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Promoted Combustion Test Propagation Rate Data

J. Borstorff, P. Jones, and F. Lowery
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June 2002

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TECHNICAL MEMORANDUM

PROMOTED COMBUSTION TEST PROPAGATION RATE DATA

1. INTRODUCTION

Combustion propagation rate data were examined for potential use in benchmarking a thermal model of the Promoted Combustion Test (PCT) and for potential use in measuring the repeatability of PCT results. Propagation rates as functions of chamber pressure were compiled both from standard test records and from detailed examination of PCT videotapes. The results displayed in the data sheets (see appendices) demonstrate (1) a very weak dependence of propagation rate on pressure and (2) improved repeatability (reduced scatter) of propagation rate at any pressure when the rate is calculated from frame-by-frame examination of PCT videotapes.

2. BACKGROUND INFORMATION

Propagation rate data acquired from the PCT are typically calculated by dividing the burn length (initial length minus final length) of the rod by the time that it took for the sample to burn. This is referred to as the standard propagation rate. A problem arises in determining the elapsed time of the burn. Calculation procedures vary from sample to sample and operator to operator due to the difficulty in judging when the test is complete and thus when to stop the timer. Some technicians wait until there is no light left in the chamber. Others stop the timer when the last drop of slag has fallen, believing that the light in the chamber, late in the test, is caused by burning slag in the drip cup instead of combustion on the rod. Further uncertainty is introduced by variation in the start of the timer. Uncertainty in the calculation procedure contributes to uncertainty and perceived variation in the recorded propagation rate.

3. PLAN OF THE EXPERIMENT

Recent PCT videotapes were reviewed in an effort to make the propagation rate calculation more accurate and consistent. Video records of each test were examined in detail. The rod length and time were noted after every drop of a molten slag ball. The unconsumed rod lengths were measured as continuous functions of the test run time. Consumed length was plotted against time. The propagation rate derived from the slope of this line is referred to as the detailed propagation rate. Detailed propagation rates have been plotted against pressure for eight different materials; these data are shown in the appendices. Detailed propagation rates for several materials are plotted against pressure (one material per data

sheet), and power law functions are fit to the data. The density, thermal conductivity, specific heat, melting point, and composition of each material are also recorded on the data sheets. The materials addressed include one low-alloy steel, two nickel alloys, four stainless steels, and one cobalt alloy.

4. INTERPRETATION OF RESULTS

The detailed propagation rates increase with pressure for all but one of these materials, although this increase is rather slight (proportional to pressure to the power of 0.2 to 0.5). This conclusion would have been difficult to make if only standard propagation rate data were available, because of the scatter of these data.

Propagation rates calculated by standard (nondetailed) methods, as recorded on the original test record data sheets, are also shown in the data sheets in the appendices for comparison. The scatter of the detailed propagation rates as functions of pressure are much lower than those of the standard propagation rates. Therefore, it appears that repeatability of PCT results might be better than had been thought, at least regarding propagation rate.

It should be noted that the detailed propagation rate method is not accurate if the sample does not drip at least four times. Further, neither the detailed nor the standard propagation rates are accurate for materials which self-extinguish immediately after ignition, because the burned length is more a result of the energy of ignition than of combustion of the material.

5. CONCLUSION

The results acquired from combustion propagation rate data demonstrate a very weak dependence of propagation rate on pressure, and an improved repeatability of PCT testing.

APPENDIX A—LOW-ALLOY STEEL

A.1 CF 4130

No. 1886F
Low-Alloy Steel

Composition:

Fe =	Cr =	Mn =	C =	Mo =
Bal.	0.95	0.5	0.3	0.2

Density: 7.83 mg/m^3

Thermal Conductivity (W/m•K):

100 °C	300 °C	500 °C	700 °C	1,000 °C	1,200 °C
42.7	40.6	37.3	31.0	28.1	30.1

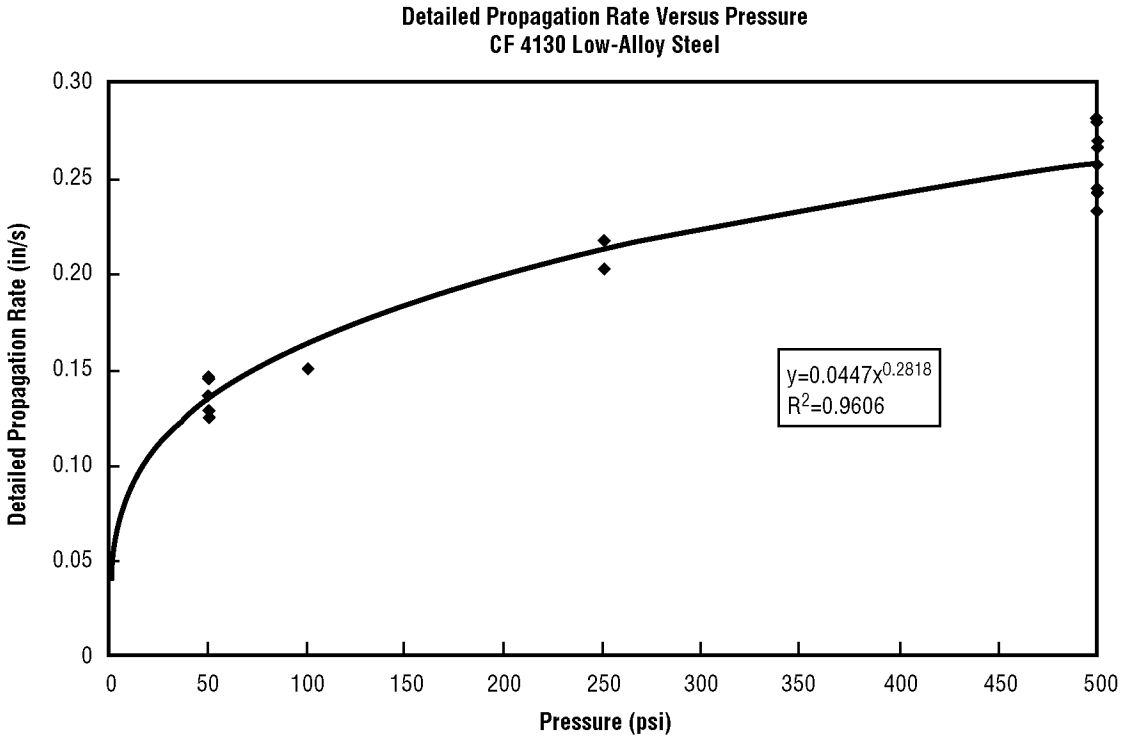
Mean Apparent Specific Heat (J/kg•K) (448 J/kg•K @ 22 °C):

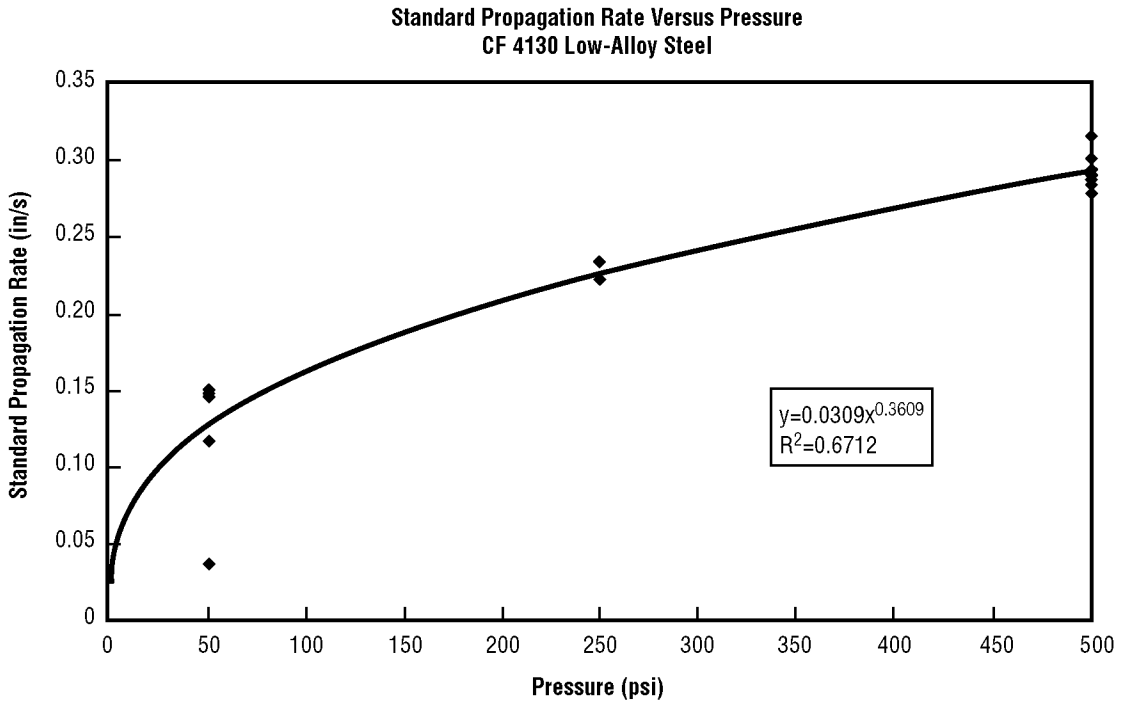
50–100 °C	150–200 °C	250–300 °C	350–400 °C	450–500 °C	550–600 °C	650–700 °C	750–800 °C
477	515	544	595	657	737	825	833

Melting Point: 1,535 °C

Sample No.	Pressure (in)	Burn Length Rate (in/s)	StandardPropagation Rate (in/s)	Detailed Propagation (Mpa)	Pressure Rate	Detailed Propagation (mm/s)
1	500	12.00	0.2899	0.2997	3.447	7.611
2	500	12.00	0.2874	0.3144	3.447	7.985
3	500	12.00	0.2931	0.3474	3.447	8.825
4	500	12.00	0.2992	0.3415	3.447	8.675
5	500	12.00	0.2771	0.3305	3.447	8.396
6	500	12.00	0.3141	0.3606	3.447	9.159
7	500	12.00	0.2899	0.3425	3.447	8.699
8	500	12.00	0.2857	0.3321	3.447	8.435
9	500	12.00	0.2827	0.3627	3.447	9.212
10	500	12.00	0.2859	0.3126	3.447	7.940
1	250	12.00	0.2341	0.2625	1.724	6.668
2	250	12.00	0.2237	0.2608	1.724	6.624
3	250	12.00	0.2346	0.2798	1.724	7.107
1	100	-----	-----	0.1931	0.689	4.905
1	50	12.00	0.1486	0.1616	0.345	4.104
2	50	12.00	0.1503	0.1655	0.345	4.204
3	50	12.00	0.1497	0.1895	0.345	4.814
4	50	12.00	0.1487	0.1676	0.345	4.256
5	50	12.00	0.1462	0.1874	0.345	4.759
6	50	0.14	0.0373	xxx	0.345	xxx
7	50	12.00	0.1513	0.1751	0.345	4.448
8	50	12.00	0.1480	0.1893	0.345	4.807
9	50	12.00	0.1497	0.1668	0.345	4.237
10	50	0.20	0.1176	xxx		xxx

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.
----- Miscellaneous problem.
Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
CF 4130 Low-Alloy Steel
Detailed Propagation Rate (in/s)
0.30
0.25
0.20
0.15
0.10
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Pressure (psi)
y=0.0447x^0.2818
R^2=0.9606


Standard Propagation Rate Versus Pressure
CF 4130 Low-Alloy Steel
Standard Propagation Rate (in/s)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
50
100
150
200
250
300
350
400
450
500
Pressure (psi)
y=0.0309x^0.3609
R^2=0.6712

APPENDIX B—NICKEL ALLOYS

B.1 Rene 41

Round Bar
Nickel-Based Alloy (Superalloy)

Composition:

Ni =	Cr =	Co =	Mo =	Ti =	Al =
55.0	19.0	11.0	10.0	3.1	1.5

Density: 8.25 mg/m^3

Melting Temperature:
Liquidus 1,371 °C
Solidus 1,232 °C

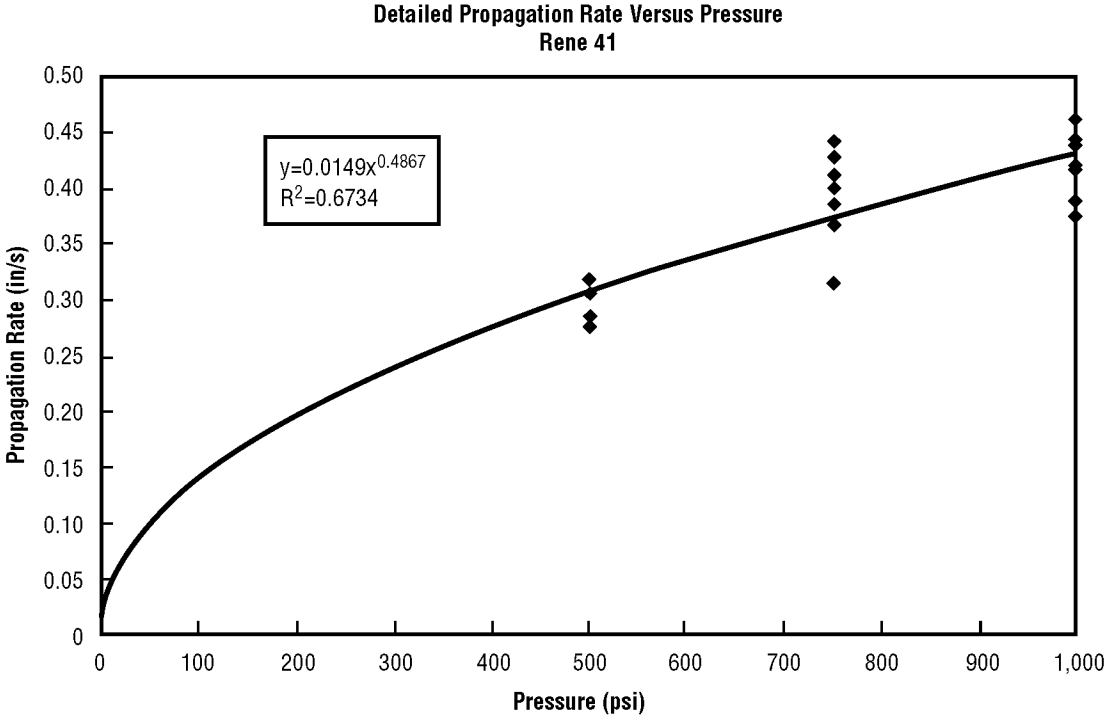
Specific Heat:
492 J/kg•K
368 J/kg•K @ 22 °C

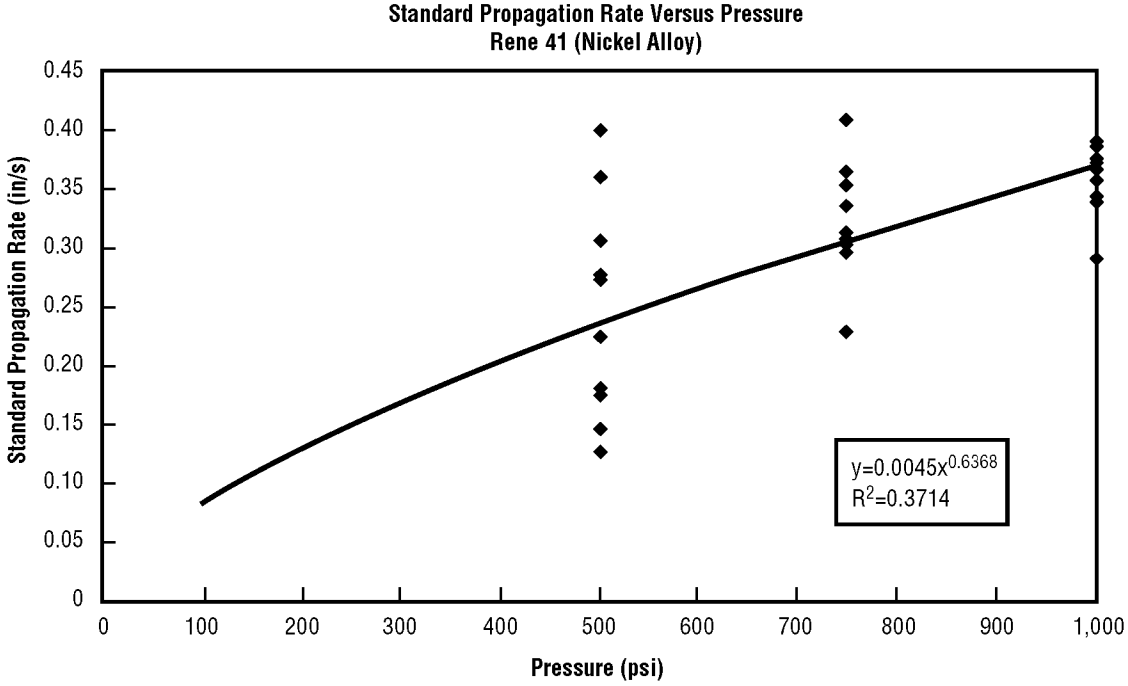
Thermal Conductivity W/m•K:
200 °F (100 °C) 10.73
1,000 °F 17.82
1,600 °F 23.01

Melting Range: 1,316 –1,371 °C

Sample No.	Pressure (psi)	Burn Length (in)	Standard Propagation Rate (in/s)	Detailed Propagation Rate (in/s)	Pressure (Mpa)	Detailed Propagation Rate (mm/s)
1	1,000	5.74	0.3742	0.4411	6.895	11.205
2	1,000	7.16	0.3573	0.3878	6.895	9.850
3	1,000	3.25	0.3652	0.3737	6.895	9.491
4	1,000	2.27	0.3424	0.4195	6.895	10.654
5	1,000	2.31	0.3377	0.4181	6.895	10.619
6	1,000	1.98	0.3708	-----	6.895	-----
7	1,000	0.64	0.2896	xxx	6.895	xxx
8	1,000	12.00	0.3653	0.4605	6.895	11.696
9	1,000	12.00	0.3862	0.4164	6.895	10.577
10	1,000	7.41	0.3837	0.4386	6.895	11.140
1	750	0.72	0.3025	-----	5.171	-----
2	750	1.53	0.4080	0.4415	5.171	11.214
3	750	5.98	0.3137	0.3845	5.171	9.765
4	750	12.00	0.3522	0.3985	5.171	10.123
5	750	2.24	0.3111	0.4265	5.171	10.834
6	750	2.63	0.3363	0.3654	5.171	9.281
7	750	1.08	0.2278	0.3150	5.171	8.002
8	750	0.76	0.3636	0.3978	5.171	10.104
9	750	1.67	0.3087	0.4102	5.171	10.419
10	750	4.69	0.2963	0.3829	5.171	9.725
1	500	0.72	0.1748	0.3166	3.447	8.043
2	500	0.47	0.1464	0.2844	3.447	7.224
3	500	0.55	0.2736	xxx	3.447	xxx
4	500	0.51	0.2757	xxx	3.447	xxx
5	500	0.32	0.2238	xxx	3.447	xxx
6	500	0.85	0.3602	0.2764	3.447	7.020
7	500	0.95	0.3992	xxx	3.447	xxx
8	500	0.45	0.3061	xxx	3.447	xxx
9	500	0.38	0.1792	xxx	3.447	xxx
10	500	0.64	0.1260	0.3057	3.447	7.765

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.
----- Miscellaneous problem.
Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
Rene 41
y=0.0149x^0.4867
R2=0.6734
Propagation Rate (in/s)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)


Standard Propagation Rate Versus Pressure
Rene 41 (Nickel Alloy)
y=0.0045x^0.6368
R2=0.3714
Standard Propagation Rate (in/s)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)

B.2 Inconel™ 601

Round Bar HR Pickled Special Study
Nickel-Based Alloy

Composition:

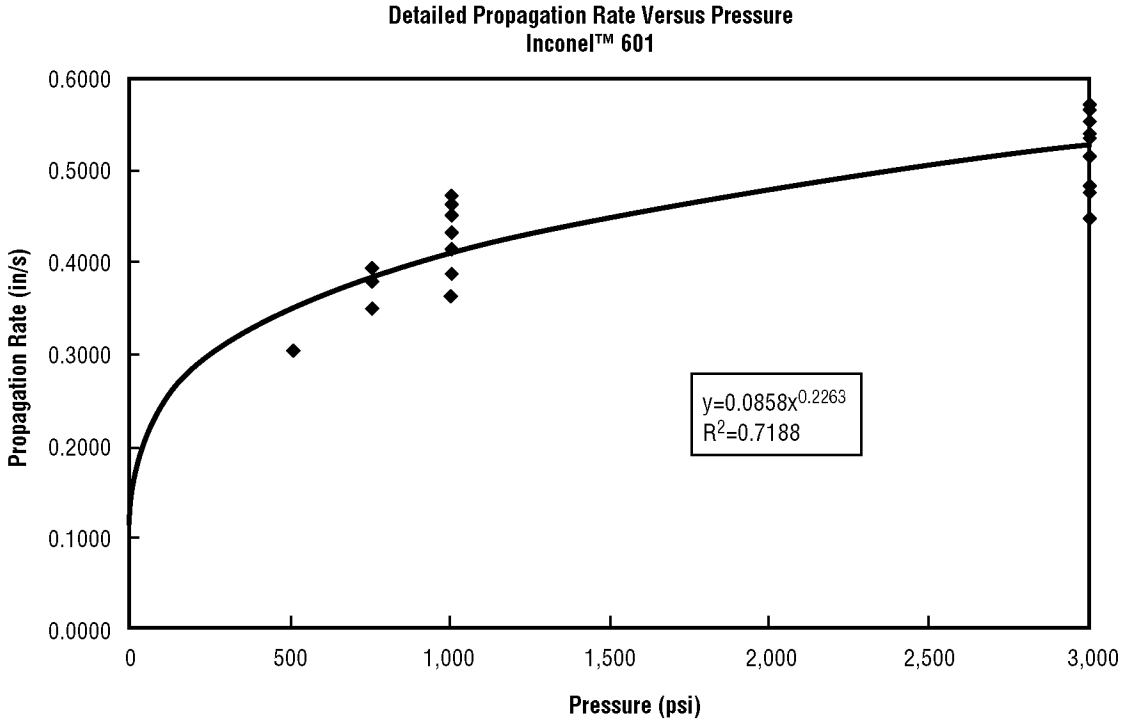
Ni =	Cr =	Fe =	Al =
60.5	23.0	14.1	1.35

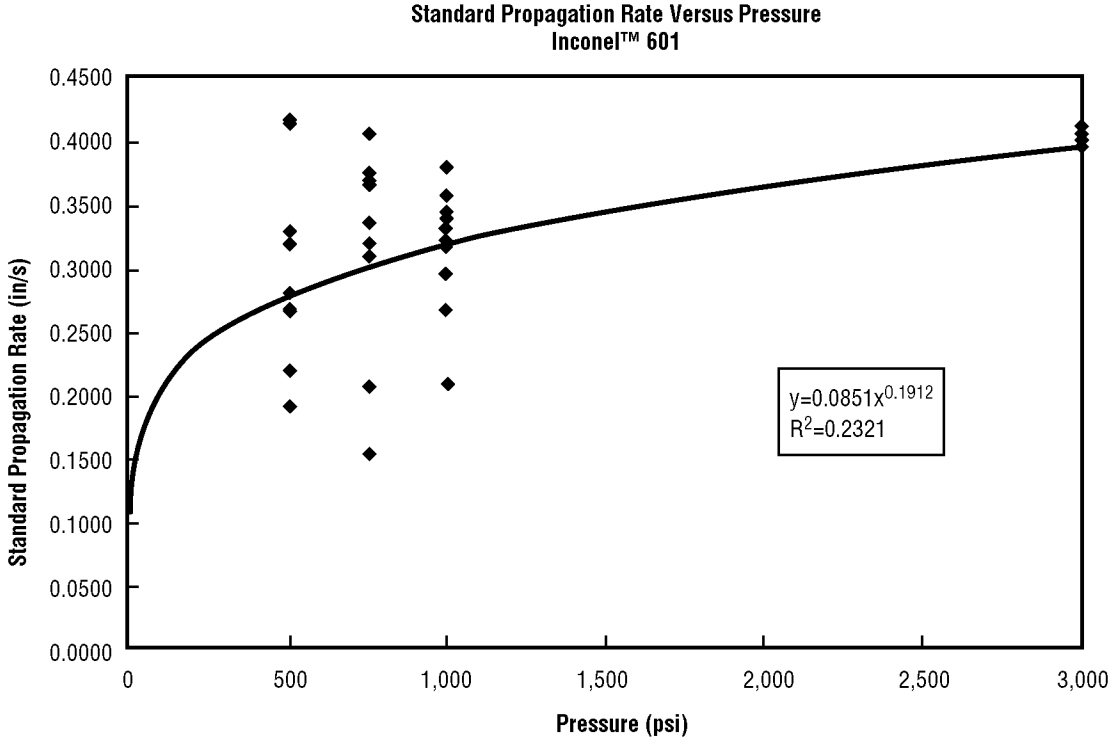
Density: 8.3 mg/m^3 @ 20 °C

Melting Temperature: 1,370–1,400 °C

Sample No.	Pressure (psi)	Burn Length (in)	Standard Propagation Rate (in/s)	Detailed Propagation Rate (in/s)	Pressure (Mpa)	Detailed Propagation Rate (mm/s)
1	3,000	12.00	0.3996	0.5675	20.68	14.415
2	3,000	12.00	0.4011	0.5524	20.68	14.031
3	3,000	12.00	0.4044	0.4473	20.68	11.361
4	3,000	12.00	0.4038	0.5704	20.68	14.489
5	3,000	12.00	0.4105	0.5141	20.68	13.057
6	3,000	12.00	0.4034	-----	20.68	-----
7	3,000	12.00	0.3997	0.4762	20.68	12.095
8	3,000	12.00	0.4050	0.5361	20.68	13.618
9	3,000	12.00	0.3946	0.4814	20.68	12.228
10	3,000	12.00	0.3946	0.5391	20.68	13.692
1	1,000	5.85	0.3223	0.4642	6.89	11.791
2	1,000	7.10	0.3321	0.4515	6.89	11.468
3	1,000	4.90	0.3574	0.4136	6.89	10.504
4	1,000	12.00	0.3446	0.4716	6.89	11.978
5	1,000	5.42	0.3800	0.4523	6.89	11.487
6	1,000	3.65	0.3174	0.3624	6.89	9.205
7	1,000	4.52	0.2960	0.3867	6.89	9.822
8	1,000	0.21	0.2100	xxx	6.89	xxx
9	1,000	0.35	0.3398	xxx	6.89	xxx
10	1,000	4.70	0.2673	0.4320	6.89	10.973
1	750	0.40	0.3704	xxx	5.17	xxx
2	750	0.31	0.1535	xxx	5.17	xxx
3	750	4.58	0.3205	0.3779	5.17	9.599
4	750	0.39	0.1548	xxx	5.17	xxx
5	750	4.57	0.3365	-----	5.17	-----
6	750	12.00	0.4066	0.3931	5.17	9.985
7	750	3.40	0.3757	xxx	5.17	xxx
8	750	3.75	0.3107	0.3493	5.17	8.873
9	750	0.37	0.3663	xxx	5.17	xxx
10	750	0.42	0.2069	xxx	5.17	xxx
1	500	0.43	0.4135	xxx	3.45	xxx
2	500	0.24	0.3200	xxx	3.45	xxx
3	500	0.45	0.4167	xxx	3.45	xxx
4	500	0.29	0.2816	xxx	3.45	xxx
5	500	0.20	0.1923	xxx	3.45	xxx
6	500	0.33	0.3300	xxx	3.45	xxx
7	500	0.33	0.3300	xxx	3.45	xxx
8	500	1.35	0.2689	0.3036	3.45	7.712
9	500	0.23	0.2212	xxx	3.45	xxx
10	500	0.27	0.2673	-----	3.45	-----

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.
----- Miscellaneous problem.
Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
Inconel™ 601
Propagation Rate (in/s)
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0
500
1,000
1,500
2,000
2,500
3,000
Pressure (psi)
y=0.0858x^0.2263
R^2=0.7188


Standard Propagation Rate Versus Pressure
Inconel™ 601
Standard Propagation Rate (in/s)
0.4500
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
0
500
1,000
1,500
2,000
2,500
3,000
Pressure (psi)
y=0.0851x^0.1912
R^2=0.2321

APPENDIX C—STAINLESS STEELS

C.1 CRES 15–5PH

Stainless Steel

Composition:

Fe =	Cr =	Ni =	C =
Bal.	15.04	4.64	3.32

Density: 7.8 mg/m^3

Specific Heat:
420 J/kg•K

Thermal Conductivity (W/m•K):

100 °C	500 °C
17.8	23.0

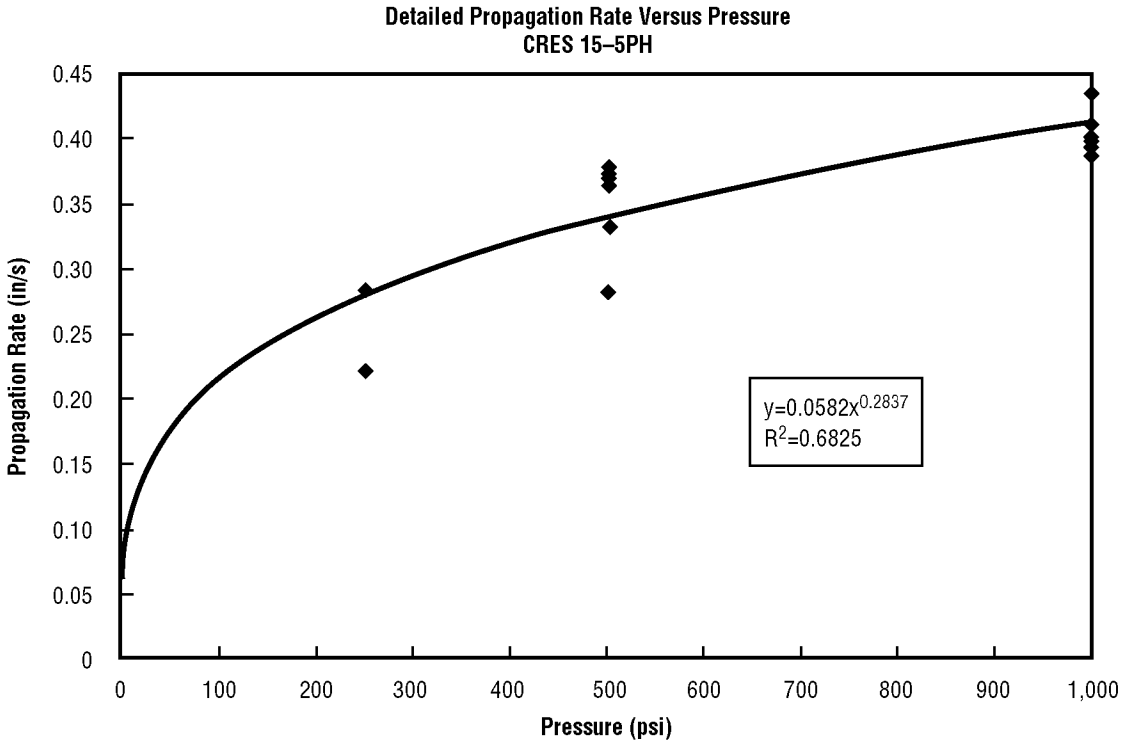
Melting Range:
1,400–1,440 °C

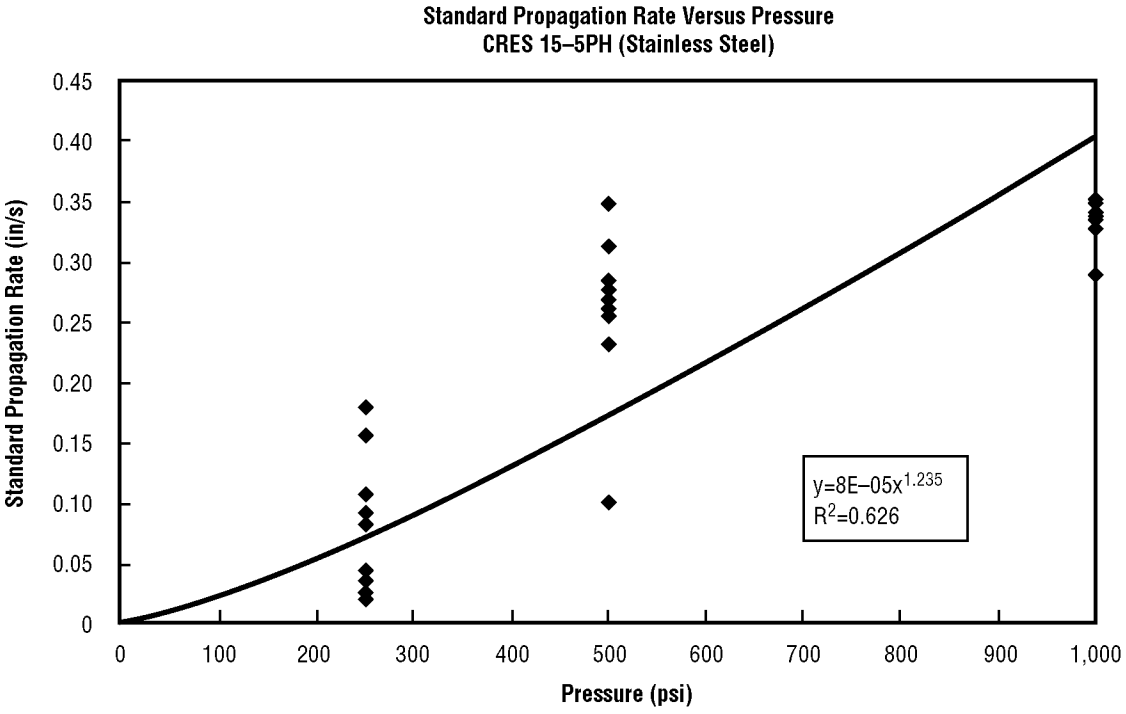
Sample No.	Pressure (psi)	Burn Length (in)	Standard Propagation Rate (in/s)	Detailed Propagation Rate (in/s)	Pressure (Mpa)	Detailed Propagation Rate (mm/s)
1	1,000	12.00	0.3339	0.4120	6.895	10.466
2	1,000	12.00	0.3402	0.4122	6.895	10.469
3	1,000	12.00	0.3327	0.4359	6.895	11.073
4	1,000	4.20	0.2875	0.4019	6.895	10.207
5	1,000	12.00	0.3380	0.4008	6.895	10.181
6	1,000	12.00	0.3362	0.3990	6.895	10.135
7	1,000	12.00	0.3270	0.4102	6.895	10.420
8	1,000	12.00	0.3474	0.3941	6.895	10.011
9	1,000	12.00	0.3365	0.3933	6.895	9.991
10	1,000	12.00	0.3507	0.3870	6.895	9.829
1	500	5.50	0.2819	0.3740	3.447	9.499
2	500	2.70	0.2839	0.3729	3.447	9.472
3	500	4.90	0.2316	0.3321	3.447	8.436
4	500	6.00	0.3476	0.3630	3.447	9.219
5	500	2.30	0.2541	0.3712	3.447	9.430
6	500	8.30	0.2775	0.3698	3.447	9.392
7	500	5.30	0.2688	0.3780	3.447	9.601
8	500	12.00	0.3129	0.3721	3.447	9.451
9	500	0.57	0.1005	xxx	3.447	xxx
10	500	4.76	0.2615	0.2815	3.447	7.150
1	250	0.26	0.0197	xxx	1.724	xxx
2	250	0.31	0.0347	xxx	1.724	xxx
3	250	0.64	0.0920	xxx	1.724	xxx
4	250	0.26	0.0245	xxx	1.724	xxx
5	250	0.22	0.0355	xxx	1.724	xxx
6	250	1.01	0.1571	0.2218	1.724	5.633
7	250	0.20	0.0826	xxx	1.724	xxx
8	250	0.25	0.0441	xxx	1.724	xxx
9	250	0.64	0.1077	xxx	1.724	xxx
10	250	2.19	0.1802	0.2833	1.724	7.197

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.

----- Miscellaneous problem.

Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
CRES 15–5PH
Propagation Rate (in/s)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)
y=0.0582x^0.2837
R^2=0.6825


Standard Propagation Rate Versus Pressure
CRES 15–5PH (Stainless Steel)
Standard Propagation Rate (in/s)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)
y=8E–05x^1.235
R^2=0.626

C.2 CRES 17–4PH

No. 8656141
Wrought Stainless Steel Annealed Cond.

Composition:

Fe =	Cr =	Ni =	Cu =
Bal.	15.2	4.09	3.8

Density: 7.8 mg/m^3

Melting Temperature:
1,400–1,440 °C

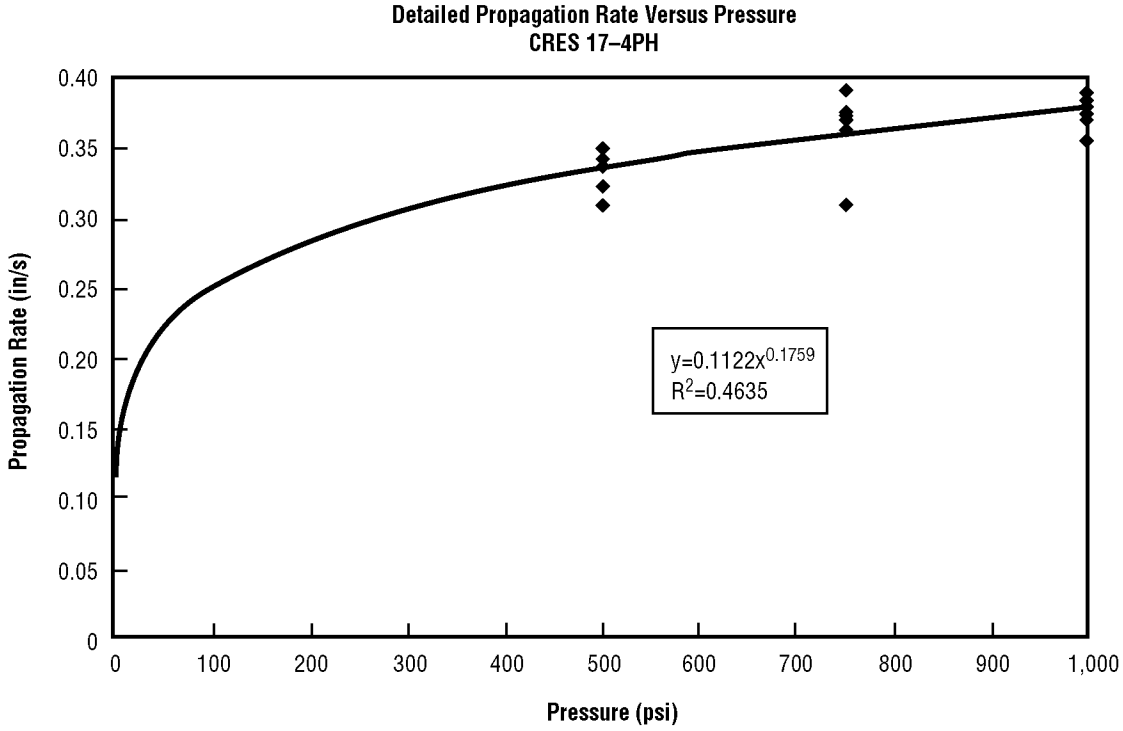
Specific Heat:
460 J/kg•K

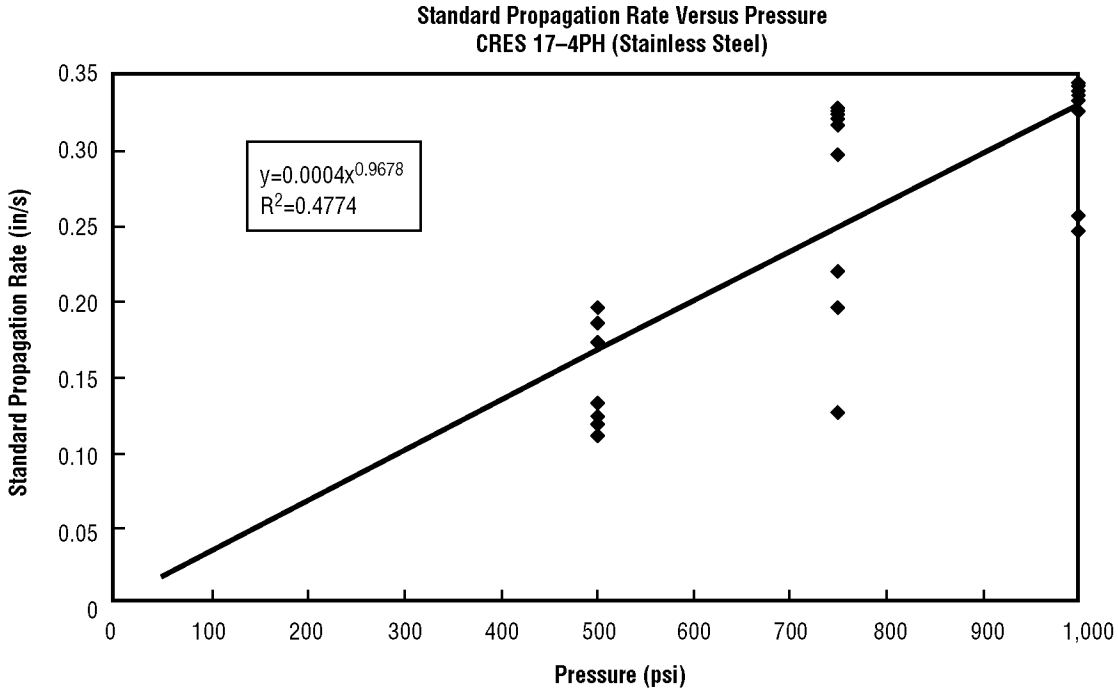
Thermal Conductivity (W/m•K):

100 °C	500 °C
18.3	23.0

Sample No.	Pressure (psi)	Burn Length (in)	Standard Propagation Rate (in/s)	Detailed Propagation Rate (in/s)	Pressure (Mpa)	Detailed Propagation Rate (mm/s)
1	1,000	12.00	0.3237	-----	6.895	-----
2	1,000	12.00	0.3336	-----	6.895	-----
3	1,000	1.70	0.2545	0.3790	6.895	9.628
4	1,000	1.40	0.2439	0.3895	6.895	9.892
5	1,000	12.00	0.3228	0.3730	6.895	9.474
6	1,000	12.00	0.3427	0.3691	6.895	9.374
7	1,000	12.00	0.3304	0.3750	6.895	9.525
8	1,000	12.00	0.3368	0.3778	6.895	9.597
9	1,000	12.00	0.3411	0.3539	6.895	8.989
10	1,000	12.00	0.3358	0.3833	6.895	9.736
1	750	12.00	0.3228	0.3686	5.171	9.363
2	750	0.70	0.1246	xxx	5.171	xxx
3	750	12.00	0.3144	0.3625	5.171	9.208
4	750	12.00	0.3190	0.3685	5.171	9.360
5	750	4.70	0.3264	0.3911	5.171	9.934
6	750	12.00	0.3202	0.3615	5.171	9.181
7	750	2.50	0.2955	0.3757	5.171	9.543
8	750	9.60	0.2180	0.3724	5.171	9.459
9	750	12.00	0.3160	0.3723	5.171	9.457
10	750	1.20	0.1936	0.3081	5.171	7.826
1	500	0.90	0.1718	xxx	3.447	xxx
2	500	1.10	0.1316	0.3090	3.447	7.850
3	500	1.10	0.1943	0.3495	3.447	8.876
4	500	0.70	0.1101	xxx	3.447	xxx
5	500	4.00	0.3012	0.3226	3.447	8.195
6	500	1.50	0.1847	0.3365	3.447	8.547
7	500	0.70	0.1178	xxx	3.447	xxx
8	500	0.70	0.1228	xxx	3.447	xxx
9	500	4.00	0.3023	0.3417	3.447	8.678
10	500	0.60	0.1097	xxx	3.447	xxx

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.
----- Miscellaneous problem.
Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
CRES 17–4PH
Propagation Rate (in/s)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)
y=0.1122x^0.1759
R^2=0.4635


Standard Propagation Rate Versus Pressure
CRES 17–4PH (Stainless Steel)
Standard Propagation Rate (in/s)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)
y=0.0004x^0.9678
R^2=0.4774

C.3 CRES 316 CF

Cold Finished Bar Round H No. 1776–33
Stainless Steel

Composition:

Fe =	Cr =	Ni =	Mo =	Mn =
Bal.	16.8	11.2	2.1	1.4

Density: 8.0 mg/m^3

Melting Temperature:
1,375–1,400 °C

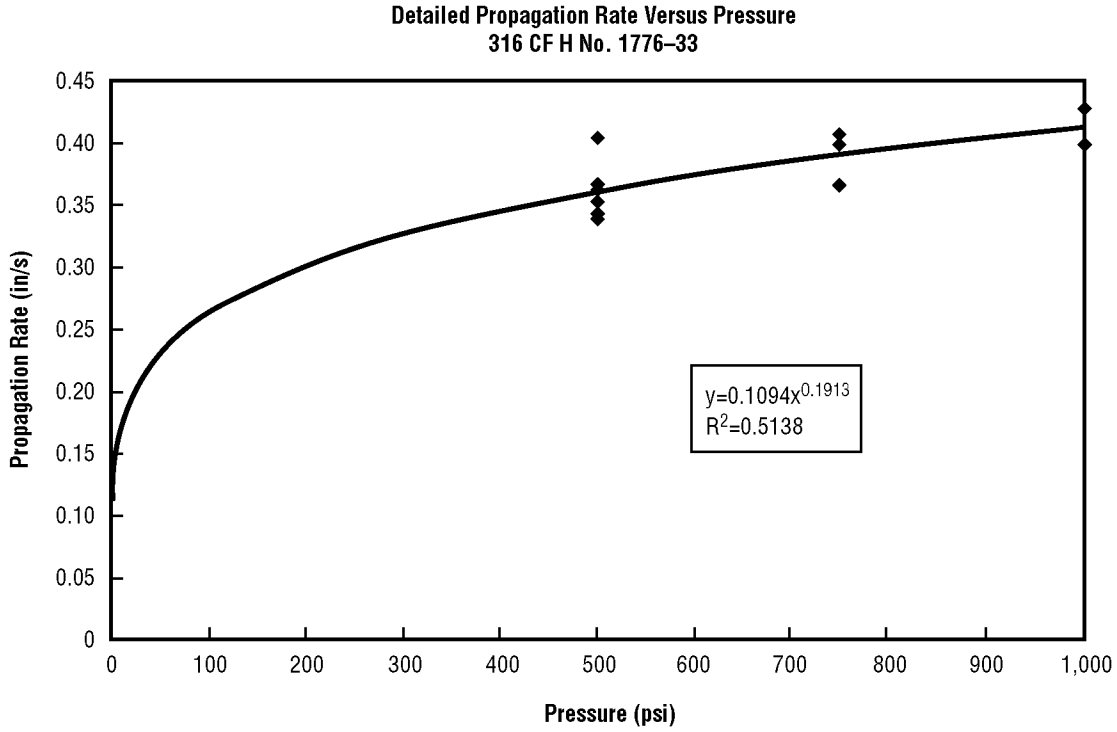
Specific Heat:
500 J/kg•K

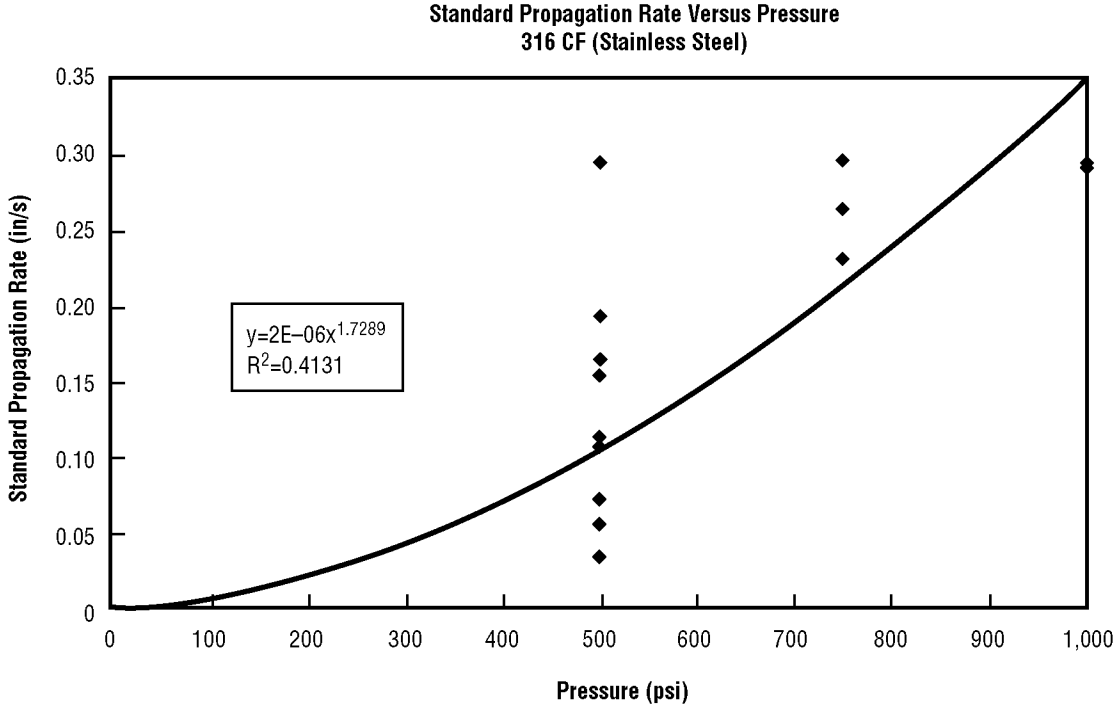
Thermal Conductivity (W/m•K):

100 °C	500 °C
16.2	21.5

Sample No.	Pressure (psi)	Burn Length (in)	Standard Propagation Rate (in/s)	Detailed Propagation Rate (in/s)	Pressure (Mpa)	Detailed Propagation Rate (mm/s)
1	1,000	12.00	0.290	0.4250	6.895	10.794
2	1,000	12.00	0.292	0.3953	6.895	10.042
1	750	12.00	0.295	0.3957	5.171	10.051
2	750	4.25	0.230	0.3640	5.171	9.246
3	750	12.00	0.264	0.4059	5.171	10.311
1	500	2.88	0.154	0.4023	3.447	10.220
2	500	0.69	0.071	xxx	3.447	xxx
3	500	0.38	0.034	xxx	3.447	xxx
4	500	0.88	0.056	xxx	3.447	xxx
5	500	3.89	0.193	0.3373	3.447	8.568
6	500	0.69	0.055	0.3512	3.447	8.921
7	500	12.00	0.295	0.3613	3.447	9.177
8	500	0.38	0.108	xxx	3.447	xxx
9	500	1.31	0.113	0.3420	3.447	8.687
10	500	3.50	0.164	0.3637	3.447	9.238

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.
Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
316 CF H No. 1776–33
Propagation Rate (in/s)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)
y=0.1094x^0.1913
R^2=0.5138


Standard Propagation Rate Versus Pressure
316 CF (Stainless Steel)
Standard Propagation Rate (in/s)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
100
200
300
400
500
600
700
800
900
1,000
Pressure (psi)
y=2E–06x^1.7289
R^2=0.4131

C.4 CRES 422 CG Ann.

Wrought Stainless Steels Annealed Condition

Melting Temperature
1,470–1,480 °C

Density: 7.8 mg/m^3

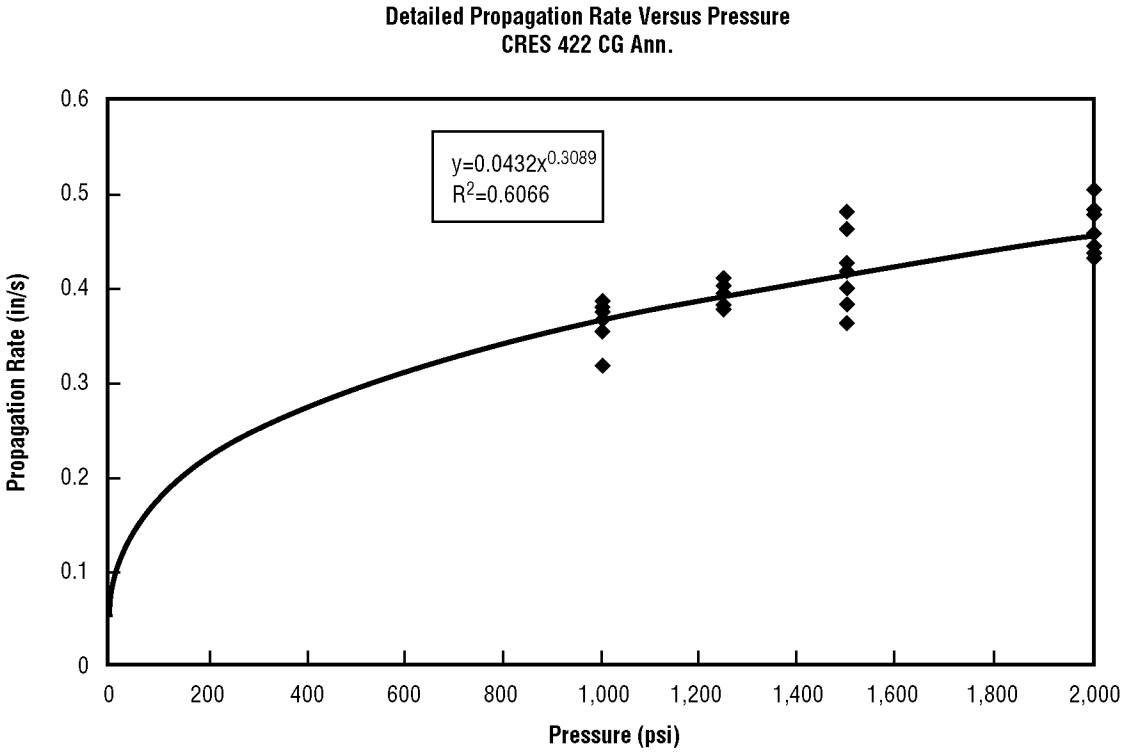
Composition:
Fe = Cr = W = Mo =

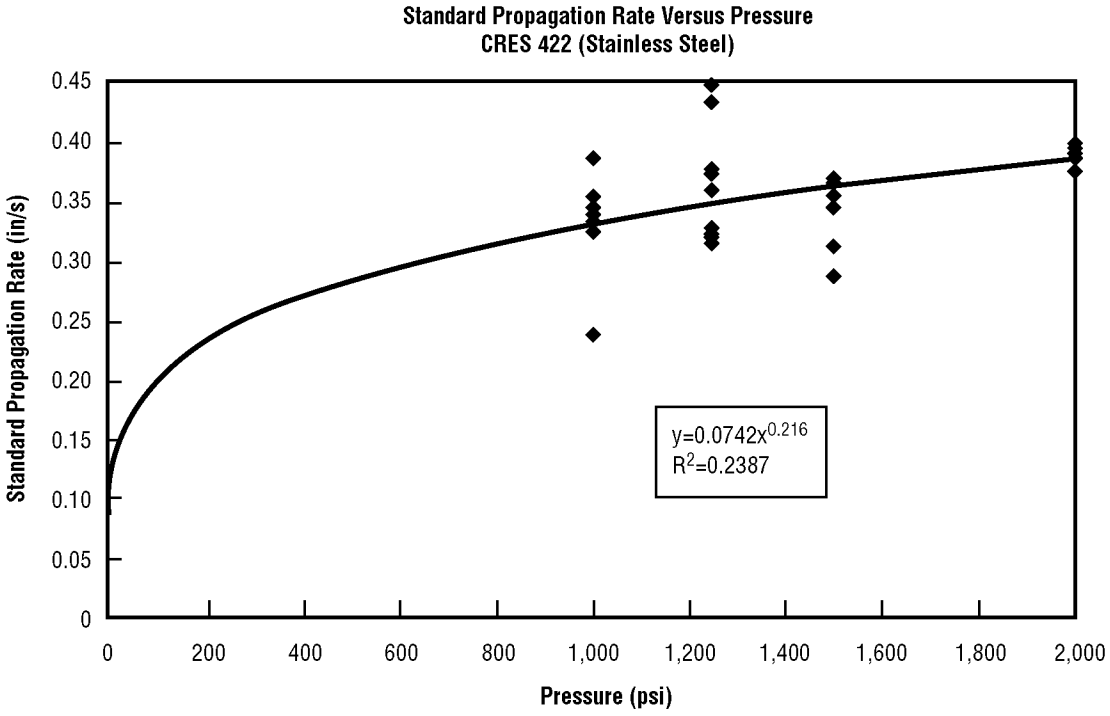
Thermal Conductivity (W/m•K):

Specific Heat:	100 °C	500 °C
460 J/kg•K	23.9	27.3

Sample No.	Pressure (psi)	Burn Length (in)	Standard Propagation Rate (in/s)	Detailed Propagation Rate (in/s)	Pressure (Mpa)	Detailed Propagation Rate (mm/s)
1	2,000	12.00	0.3847	0.4354	13.790	11.060
2	2,000	12.00	0.3910	0.4746	13.790	12.055
3	2,000	12.00	0.3877	0.5032	13.790	12.782
4	2,000	12.00	0.3823	0.4567	13.790	11.599
5	2,000	12.00	0.3964	0.4419	13.790	11.224
6	2,000	12.00	0.3729	0.4803	13.790	12.201
7	2,000	12.00	0.3975	-----	13.790	-----
8	2,000	12.00	0.3844	0.4331	13.790	11.000
9	2,000	12.00	0.3942	0.4323	13.790	10.979
10	2,000	12.00	0.3915	0.4305	13.790	10.935
1	1,500	12.00	0.3647	0.4615	10.342	11.722
2	1,500	1.10	0.3642	0.4008	10.342	10.180
3	1,500	12.00	0.3581	0.3823	10.342	9.709
4	1,500	12.00	0.3655	0.4803	10.342	12.200
5	1,500	12.00	0.3674	0.4169	10.342	10.588
6	1,500	0.18	0.2857	xxx	10.342	xxx
7	1,500	4.35	0.3441	0.3819	10.342	9.701
8	1,500	7.37	0.3536	0.4262	10.342	10.825
9	1,500	12.00	0.3686	0.3978	10.342	10.104
10	1,500	4.61	0.3102	0.3611	10.342	9.172
1	1,250	0.88	0.3761	0.3949	8.618	10.029
2	1,250	1.88	0.3181	0.3813	8.618	9.684
3	1,250	6.50	0.3215	0.4101	8.618	10.416
4	1,250	1.08	0.3711	0.4014	8.618	10.195
5	1,250	1.12	0.4462	0.3923	8.618	9.963
6	1,250	1.51	0.3199	0.3970	8.618	10.083
7	1,250	0.36	0.3130	xxx	8.618	xxx
8	1,250	4.13	0.3275	0.4037	8.618	10.254
9	1,250	1.26	0.3590	0.3763	8.618	9.557
10	1,250	0.58	0.4328	xxx	8.618	xxx
2	1,000	2.91	0.3322	-----	6.895	-----
3	1,000	0.24	0.2376	xxx	6.895	xxx
4	1,000	3.67	0.3342	0.3747	6.895	9.519
5	1,000	2.01	0.3533	0.3862	6.895	9.810
6	1,000	0.94	0.3381	0.3545	6.895	9.005
7	1,000	0.99	0.3449	0.3653	6.895	9.279
8	1,000	1.57	0.3244	0.3173	6.895	8.059
9	1,000	3.67	0.3345	0.3788	6.895	9.622
10	1,000	2.97	0.3267	0.3796	6.895	9.643

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.
----- Miscellaneous problem.
Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
CRES 422 CG Ann.
y=0.0432x^0.3089
R^2=0.6066
Propagation Rate (in/s)
0
0.1
0.2
0.3
0.4
0.5
0.6
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Pressure (psi)


Standard Propagation Rate Versus Pressure
CRES 422 (Stainless Steel)
y=0.0742x^0.216
R^2=0.2387
Standard Propagation Rate (in/s)
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Pressure (psi)

APPENDIX D—COBALT ALLOYS

D.1 MP35N

Cobalt Alloy

Composition:

Co =	Ni =	Cr =	Mo =	Specific Heat:
35.0	35.0	20.00	10.0	753 J/kg•K

Density: 8.4 mg/m^3

Thermal Conductivity (W/m•K):
21 °C
11.07

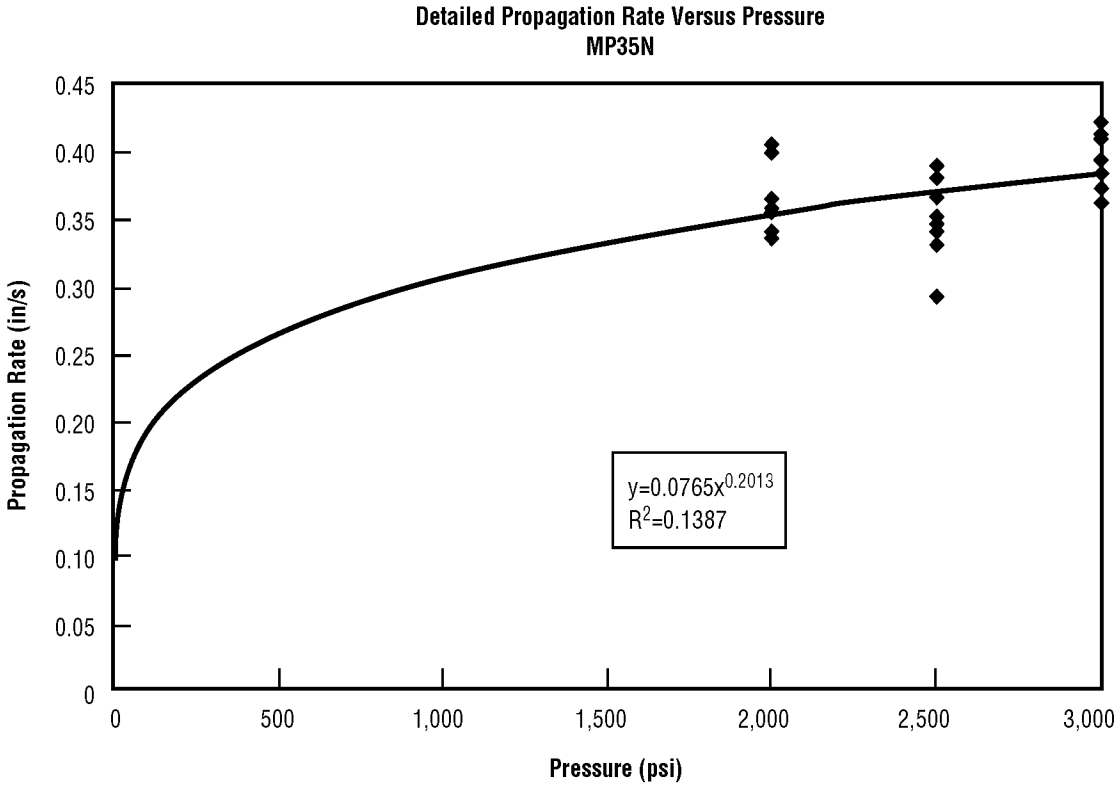
Melting Temperature:
1,315–1,426 °C

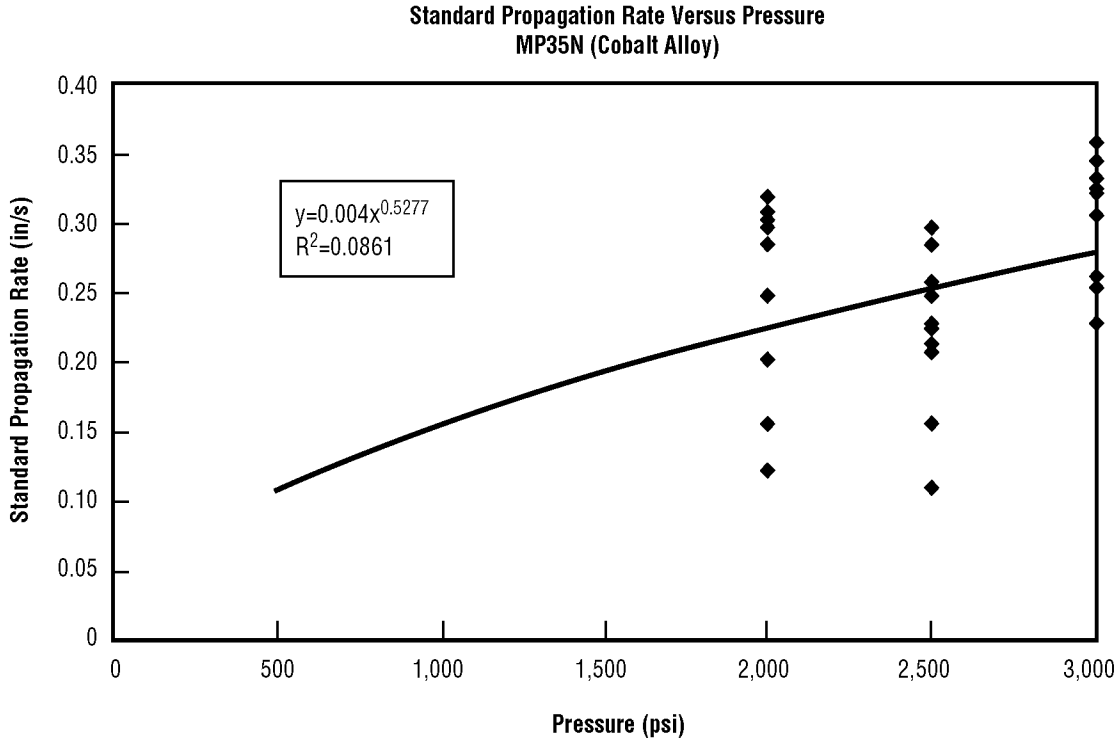
Sample No.	Pressure (psi)	Burn Length (in)	Standard Propagation Rate (in/s)	Detailed Propagation Rate (in/s)	Pressure (Mpa)	Detailed Propagation Rate (mm/s)
1	3,000	0.58	0.2590	xxx	20.684	xxx
2	3,000	12.00	0.3299	0.3832	20.684	9.734
3	3,000	3.38	0.3413	0.3723	20.684	9.457
4	3,000	3.38	0.2247	0.3935	20.684	9.994
5	3,000	1.26	0.3026	0.4085	20.684	10.376
6	3,000	2.56	0.3223	0.4206	20.684	10.683
7	3,000	5.69	0.3422	-----	20.684	-----
8	3,000	0.81	0.2506	0.3606	20.684	9.160
9	3,000	5.36	0.3201	0.4123	20.684	10.474
10	3,000	3.20	0.3548	0.4205	20.684	10.681
1	2,500	0.89	0.2834	0.3658	17.237	9.292
2	2,500	0.83	0.1539	0.2927	17.237	7.434
3	2,500	2.51	0.2118	0.3883	17.237	9.862
4	2,500	10.87	0.2946	0.3804	17.237	9.662
5	2,500	2.14	0.2257	0.3452	17.237	8.767
6	2,500	2.64	0.2225	-----	17.237	-----
7	2,500	2.26	0.2559	0.3399	17.237	8.633
8	2,500	1.26	0.2045	0.3303	17.237	8.391
9	2,500	0.39	0.1075	xxx	17.237	xxx
10	2,500	5.58	0.2455	0.3512	17.237	8.921
1	2,000	1.95	0.2459	0.3537	13.790	8.984
2	2,000	0.35	0.2991	xxx	13.790	xxx
3	2,000	1.05	0.3061	0.3395	13.790	8.624
4	2,000	0.25	0.1534	xxx	13.790	xxx
5	2,000	0.34	0.1200	xxx	13.790	xxx
6	2,000	1.40	0.2828	0.3978	13.790	10.105
7	2,000	1.15	0.2956	0.3641	13.790	9.249
8	2,000	1.10	0.2828	0.3572	13.790	9.073
9	2,000	1.95	0.3171	0.4056	13.790	10.302
10	2,000	1.30	0.2000	0.3363	13.790	8.541

xxx Detailed flame speed was only calculated for samples that exhibited dripping behavior at least four times.

----- Miscellaneous problem.

Note: A material is considered to be flammable if the sample has a burn length >6 in.


Detailed Propagation Rate Versus Pressure
MP35N
Propagation Rate (in/s)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
500
1,000
1,500
2,000
2,500
3,000
Pressure (psi)
y=0.0765x^0.2013
R^2=0.1387


Standard Propagation Rate Versus Pressure
MP35N (Cobalt Alloy)
Standard Propagation Rate (in/s)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
500
1,000
1,500
2,000
2,500
3,000
Pressure (psi)
y=0.004x^0.5277
R^2=0.0861

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13. ABSTRACT *(Maximum 200 words)*

Combustion propagation rate data were examined for potential use in benchmarking a thermal model of the Promoted Combustion Test (PCT), and also for potential use in measuring the repeatability of PCT results.

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